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Drainage basin response to natural and anthropogenic disturbance: implications for land management in the Toiyabe Range, central Nevada

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"Drainage Basin Response to Natural and Anthropogenic Disturbance: Implications for Land Management Within the Toiyabe Range"
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DRAINAGE BASIN RESPONSE TO NATURAL AND ANTHROPOGENIC DISTURBANCE: IMPLICATIONS FOR LAND MANAGEMENT IN THE TOIYABE RANGE, CENTRAL NEVADA

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SUMMARY

Channels in many upland watersheds of the Great Basin, including those in the Toiyabe Range, are severely degraded due to downcutting, compromising their ability to perform important ecological functions. The geomorphic history of selected watersheds in the Toiyabe Range was examined to provide insights into the nature of geomorphic responses to disturbance during the late Holocene. Major geomorphic events closely parallel temporal variations in vegetation and climate documented for the area using woodrat (*Neotoma*) middens. The oldest alluvial unit observed within bank exposures (Qa1) ranges from 4,180±100 to 3,450±160 YBP, and corresponds to the Neoglacial, a cool wet period characterized by a high number of plant taxa. Qa1 is buried by Qa2 deposits that interfinger with side-valley alluvial fan sediments, indicating that fan building and valley aggradation were synchronous. Radiocarbon analysis constrains the age of Qa2 and fan deposition to 1,960±50 to 2,580±70 YBP, or the onset of a severe drought when the number of plant taxa declined by >50 %. Inset into Qa2 is a strath terrace composed of Qa3 deposits. Qa3 ranges in age from 1,310±50 to 1,250±50 YBP, the onset of the Medieval Warm Period. The youngest valley fill unit, Qa4 is limited to paleochannel and overbank deposits located upstream of valley constrictions caused by side-valley alluvial fans. Qa4 dates from approximately 290 YBP, suggesting that the most recent phase of channel incision locally began prior to Anglo-American settlement. Inset below the valley floor are three gravel terraces. These terraces have been dated using dendrochronologic methods and correspond to years of unusually large runoff including the early 1970's, 1983, and 1995.

While geomorphic responses appear to be similar between basins, the nature and magnitude of the responses vary along the channel largely as a function of geomorphic position relative to the side-valley alluvial fans. Radial fan profiles suggest that the larger fans temporarily blocked the flow of water and sediment downvalley, creating a stepped longitudinal valley profile; each step corresponds to a side-valley fan. Elevation changes across the fans are generally associated with <1 m high knickpoints cut into fan sediments. Stream reaches located immediately upvalley of the fans are generally characterized by low gradients, high rates of past and present deposition on the valley floor, locally high water tables, and wet meadow ecosystem types. In contrast, reaches downvalley of the fans exhibit high gradients, limited valley floor deposition, greater depths to water tables, and woody vegetation types. These trends suggest that the fans are controlling local rates of entrenchment, and that erosionally resistant fan deposits have not allowed the active channel to develop a smooth, concave-up ("equilibrium") profile during the most recent phase of incision. Thus, modern channel dynamics appear to be strongly influenced by depositional events that occur approximately 2000 years ago.

Given the above, we suggest that pre-historic and modern geomorphic responses are primarily driven by the dynamic interplay between vegetation and hillslope soils following shifts in climate, and the evolutionary history of the valley floor. However, human-influences, particularly road construction and upland grazing, may have exacerbated channel incision within the watershed.

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I. INTRODUCTION

During the past two centuries watersheds throughout the semi-arid West have exhibited severe degradation compromising their ability to perform a number of important ecological functions. Changes within the watersheds have been attributed most often to anthropogenic disturbances that have influenced ecosystem functioning over a continuum of spatial and temporal scales. It is clear, however, that climate change, through its influence on vegetation, runoff, and sediment yields, can also lead to watershed instability (Hereford 1984, Balling and Wells 1990, Chatters and Hoover 1992, McFadden and McAuliffe 1997, Chambers et al. 1998). Recent studies have linked climate change to erosional and depositional events in arroyos, alluvial fans, and other types of fluvial systems (Karlstrom et al. 1974, Bull and Schick 1979, Karlstrom and Karlstrom 1986, Hereford 1987, Wells et al. 1987, Balling and Wells 1990, Chatters and Hoover 1992, Ritter et al. 1995, McFadden and McAuliffe 1997).

Regardless of the disturbances promoting the alterations in watershed morphodynamics, the highly degraded state of the riparian habitats has led to a dramatic increase in the number of restoration programs in the U.S., particularly the arid west. The success of these projects has been inconsistent as many have been ineffective or have completely failed (Frissel and Nawa, 1992; O'Neil and Fitch, 1992). While the shortcomings of these projects are due to a variety of factors, the lack of understanding of the geomorphic responses to both natural disturbances (e.g., climate change and tectonism) and anthropogenic disturbances (e.g., grazing, mining, logging, and road construction) is perceived as a fundamental shortcoming of the restoration and rehabilitation strategies that have been utilized.

The primary objectives of this study were to document the geomorphic history of selected basins in central Nevada during the late Holocene, and determine, to the extent possible, the disturbances that promoted change during both prehistoric and historic times. Emphasis was placed on documenting geomorphic responses to climate change, and on determining the influence of past geomorphic events on the current dynamics of the channel systems. The study also attempts to understand the relative role of natural versus anthropogenic disturbances on watershed degradation during the past two centuries.

II. STUDY AREA

This study primarily focuses on the San Juan and Cottonwood Creek basins located within the Toiyabe Range of central Nevada (Fig. 1). These two watersheds were selected for detailed analysis because bank exposures yielding important stratigraphic information were abundant along significant lengths of the valley floor. Data were also collected from the Big Creek, Kingston Canyon, and Washington Creek basins within the Toiyabe Range, the Barley Creek basin within the Monitor Range, and the Stoneberger Creek basin within the Toquima Range (Fig. 1). All of these mountains are north-south oriented, fault-blocked ranges characterized by a complex structural geology

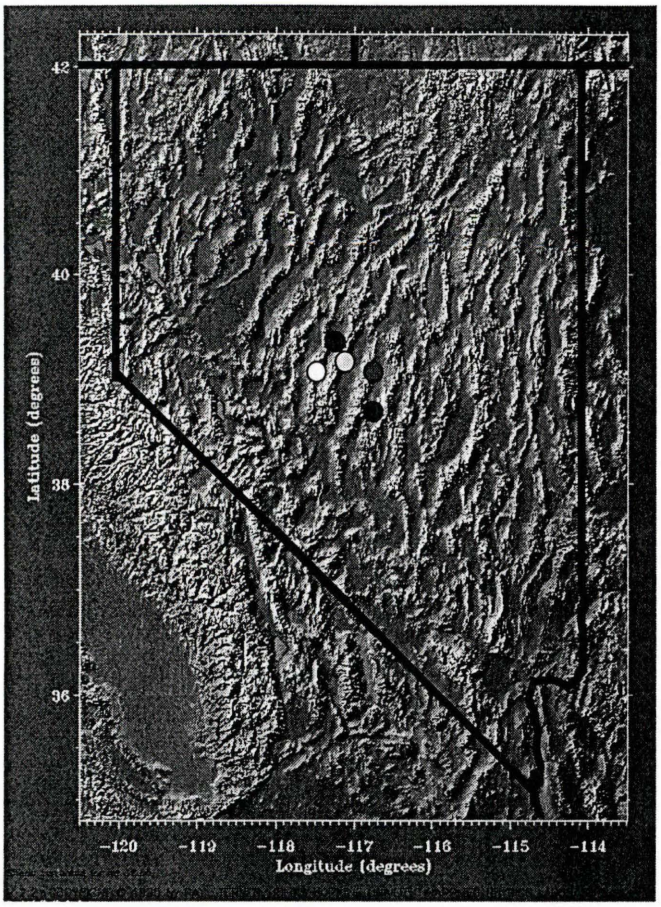


Figure 1. Location of the study basins within central Nevada

(Kleinhample and Ziony 1985). Watershed elevations range from about 1,850 to 3,200 m, with variations in precipitation ranging from 20 cm at the basin mouth to 45 cm at upper elevations. Approximately 60% of the precipitation occurs in the form of snow during the winter months. Peak runoff is in response to snowmelt in early June, but localized convective summer storms can result in flash floods. At low to middle elevations, Wyoming big sagebrush (Artemisia tridentata spp. wyomingensis) communities are interspersed with Utah juniper (Juniperus osteosperma) and single leaf pinyon (Pinus monophylla) woodlands. At higher elevations, mountain brush vegetation, including mountain big sagebrush (Artemisia tridentata spp. vaseyana), and limber pine (Pinus flexilis) dominate.

The basins are characterized by an integrated stream system that is incised into low-relief, narrow (<500 m wide) valley floors. Low flows range from about 0.015 to 0.063 m^3/s, whereas, high flows range from 0.214 to 0.683 m^3/s (Hess and Bohman 1996). In general, riparian vegetation consists of stringers of quaking aspen (Populus tremuloides), narrow leaf cottonwood (Populus angustifolia), river birch (Betula occidentalis), willows (Salix spp.), and meadow communities (USDA Forest Service 1996). At the base of the mountains, streams flow onto alluvial fans and land management changes from USDA Forest Service to USDI Bureau of Land Management. Small inholdings of private property often exist at this point, and most streams are channelized and diverted to these inholdings or to private ranches lower in the broad-central valleys.

Throughout nearly all of these watersheds, recent, localized stream incision has been a significant problem and has result in extensive ecosystem degradation. However, the magnitude and rate of incision vary from basin to basin, and along the valley floor within any given basin.

III. METHODS

The geomorphic responses to both climate change and anthropogenic disturbance were assessed by reconstructing the late Holocene geomorphic history of the watersheds and temporally and/or physically linking the defined erosional and depositional events to known changes in climate or specific types of land use. The geomorphic history of the basins were determined by delineating, characterizing, and dating the alluvial stratigraphy of the valley fill exposed in 1-3 m high bank exposures and by relating the delineated stratigraphic units to landforms (e.g., terraces and alluvial fans) observed along the valley floor. Unit delineation and characterization involved the following procedures:

(1) The identification and selection of stratigraphic sections for detailed analysis. The selection process was primarily based on the degree of unit exposure, the number of stratigraphic units present, and the presence of datable materials;

(2) The delineation of individual stratigraphic units on the basis of grain-size distribution, sediment color, clast lithology, degree of sediment weathering, and topographic/stratigraphic position;

(3) The detailed measurement of stratigraphic sections showing unit boundary geometry, unit and facies continuity, the location of collected sediment and radiocarbon samples, and the presence of surface or buried soils;

(4) The collection of samples for sedimentologic analysis and radiocarbon dating;

(5) The measurement of the grain-size distribution of sediments >2 mm in size using procedures modified from Wolman (1954); and

(6) The description of soil profiles developed in the alluvial units following the procedures of the Soil Conservation Service (1981) and Birkeland (1984).

The sedimentology of the materials in each unit was further characterized by describing clast lithology, and by determining the particle size distribution of the < 2 mm fraction in the soils laboratory at IUPUI using wet sieving and pipetting techniques. All radiocarbon analyses were conducted by Beta Analytical, located in Miami, Florida.

In addition to the data collected above, cross–valley and longitudinal profiles of selected landforms were surveyed within selected watersheds in order to: (1) define the topographic relations between the delineated stratigraphic units, and (2) quantify gradient changes along the valley floor, particularly within the vicinity of the side-valley alluvial fans. Surveys were generally collected using a Leica Total Station; however, in some localities with extremely dense vegetation, the surveys were conducted using a tape and abney level.

IV. RESULTS AND DISCUSSION

A. Overview of Valley Morphology

Upland watersheds within the Toiyabe, Toquima, and Monitor Ranges of central Nevada are commonly characterized by an integrated stream system that is incised into low-relief, narrow (<500m wide) valley floors. Valley widths are locally restricted by bedrock outcrops, and more frequently, alluvial fans that have built away from the valley sides. The larger of these fans extend almost completely across the valley floor (Fig. 2). At many of these locations, the toes of the fans have been truncated by the axial channel which is now confined between hillslope and distal alluvial fan deposits. Interestingly, nearly all of the wet meadow ecosystem types are found immediately upvalley of large alluvial fans that extend across the valley floors (Fig. 3). However, not all of the alluvial fans exhibit upstream meadows. Where the meadows do exist, stream reaches

Figure 2. Side-valley alluvial fan within Kingston Canyon which nearly traverses the entire width of the valley floor.

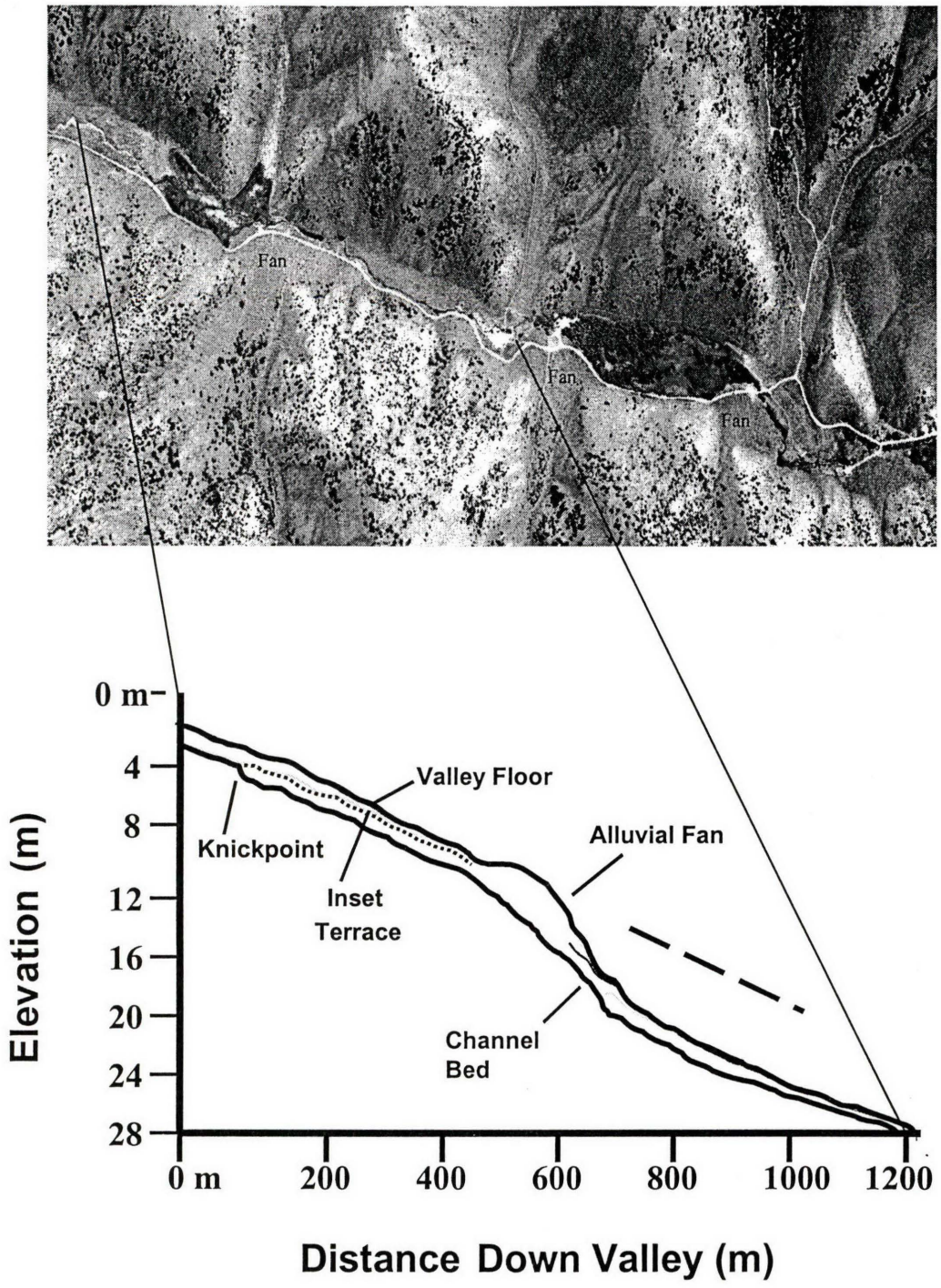


Figure 3. (A) Aerial photograph of side-valley alluvial fans in Kingston Canyon showing variations in valley morphology and vegetation types along the valley floor.
(B) Longitudinal profile along Channel bed and valley floor showing stepped nature of valley topography.

immediately upstream of the fans are characterized by lower gradients than is found either at the toe of the fans or farther downstream (Fig. 3).

Field observations reveal that the depth of incision varies along the valley floor. Entrenchment is most pronounced at or immediately upstream of the alluvial fans where meadow complexes are present. At these sites, <1m high knickpoints are commonly found cut into fan sediments or within alluvium of the wet meadows located immediately upvalley of the alluvial fans (Fig. 4). It is also common for both the active channel bed and the surface of the valley floor to dramatically drop in elevation as the channel traverses reaches constricted by the side-valley alluvial fans. These abrupt changes in elevation are clearly visible at several location within Kingston Creek (Fig. 3) where the valley floor drops by more than 3 m in elevation as the stream traverses the toe of an alluvial fan that constricts the valley width.

B. Description of Late Holocene Alluvial Stratigraphy

A detailed analysis of the late Holocene alluvial stratigraphy was carried out in the San Juan and Cottonwood Creek basins where significant bank exposures were present (Waltman et al., 1998). The analysis included the measurement of stratigraphic sections along San Juan and Cottonwood Creeks (Appendix A). In addition, a few stratigraphic sections were measured within the Barley and Stoneberger Creek basins (Fig. 1). The late Holocene stratigraphy is similar between all of the upland basins that were examined in detail. Moreover, extensive field reconnaissance suggests that while the areal extent the stratigraphic units, and magnitude of erosional events, varied between the basins, the observed stratigraphic relations are similar to those observed within the San Juan and Cottonwood Creek basins throughout most of the upland watershed of central Nevada regardless of tectonic setting. This includes the Big Creek, Kingston Canyon, and Washington Creek Basins within the Toiyabe Range which were examined as part of this investigation.

The late Holocene valley fill consists of four alluvial stratigraphic units which have been named, from oldest to youngest, Quaternary alluvial unit 1 through Quaternary alluvial unit 4 (Qa1-Qa4). In addition, three alluvial units (Qa5-Qa7) occur as inset terraces along the incised channel (Fig. 5). A brief description of each is provided below; individual stratigraphic sections that were decribed within the San Juan and Cottonwood Creek basins are presented in Appendix A.

The oldest alluvial unit exposed in bank sections was Quaternary Alluvial Unit 1 (Qa1). It is consistently found at the base of the banks, and is dominated by silt to fine sand sized material possessing varying quantities of gravel. At all localities, the exposed materials had been extensively weathered, forming a distinctive soil (Fig. 7). The soil is characterized by an organic rich A-horizon, and a 15-45 cm thick B-horizon exhibiting medium to subangular block structure. Locally, the A-horizon was overlain by laminated peat-like deposits. Radiocarbon dates of the peat, and charcoal found within the soil, ranged from 4,180$\pm$100 to 3,4050$\pm$160 YBP (Table 1; Fig. 6).

Qa2 overlies and buries Qa1. It is the most extensive alluvial unit, underlying a significant portion of the valley floor within the examined watersheds. Qa2 interfingers with side-valley alluvial fans deposits and consists of both a fine- and coarse-grained facies. The fine-grained facies is characterized by grey, interbedded sands and silts, both of which contain <10-15 % gravel dispersed throughout the material (Fig. 8). The unit also contains1-4 cm thick, discontinuous layers of dark brown silt enriched with charcoal. The coarse-grained facies is dominated by a clast supported gravel with a fine sand to sandy loam matrix. This facies typically occurred as 50-200 cm long lenses within the fine-grained facies.

The average thickness of Qa2 ranged from 30 cm to more than 150 cm. The surface of Qa2 deposits exhibit a soil profile exhibiting a 42 cm thick B-horizon. Maximum B-horizon development is characterized by a silt loam texture and a fine subangular block structure. Radiocarbon dates obtained on charcoal contained within the unit ranged from 2,580±70 to 1,960±50 YBP (Table 1; Fig. 6).

The areal extent of Qa3 is highly variable along the valley floor within any given basin, and it is not uncommon for it to be locally absent. It occurs as strath terrace deposits inset into both Qa2 and side-valley alluvial fan materials. Both a fine- and coarse-grained facies have been delineated in bank exposures (Fig. 9). The fine-grained facies is typically on the order of 40-80 cm thick, and consists of silt to sandy loam textures. The coarse-grained facies contained reworked subangular to angular, clast supported gravels with a sandy loam to fine sand matrix. Locally, the coarse-grained facies exhibits a fining upward sequence ranged from gravel to fine sand (Fig. 9). The surface of Qa3 exhibits a 15-94 cm thick soil. Maximum B-horizon development is characterized by silt loam textures, and fine to coarse subangular block structures. Radiaocarbon dates obtained on bulk humus and charcoal range from 1,310±50 and 1250±50 YBP (Table 1; Fig. 6).

Qa4 is characterized by several depositional styles, and is geographically limited to reaches of the valley floor found immediately upvalley of the alluvial fans. The most common deposits occur as paleochannel fills (Fig. 10). These deposits are characterized by poorly sorted sands and silts that are interlayered with 20-40 cm thick peat deposits. Gravel lenses are also present near the base of the paleochannel fills. The gravels are typically clast supported and contain a sand to sandy loam matrix. Locally, Qa4 deposits occur as gravel deposits that have spread out over the valley floor (Fig. 11). These deposits are similar to the gravel deposits found within the paleochannel fills, and contain a sand to sandy loam matrix. The areal extent of the overbank gravel deposits is highly variable ranging from bars confined to small areas immediately adjacent to the channel, to areas where the entire valley floor has been nearly covered by overbank gravels (Fig. 3). Radiocarbon dates suggest that the deposition of Qa4 began after appoximately 290±50 YBP (Table 1; Fig. 6).

Qa5, Qa6, and Qa7 represent areally restricted units inset within the valley fill (Fig. 12). They are all composed of gravel sized material, and can be distinguished only on the basis of elevation above the modern channel bed. The maximum age of these

Figure 4. Knickpoint advancing through wet meadow complex located immediate upstream of side-valley alluvial fan within Indiana Meadow, central Nevada.

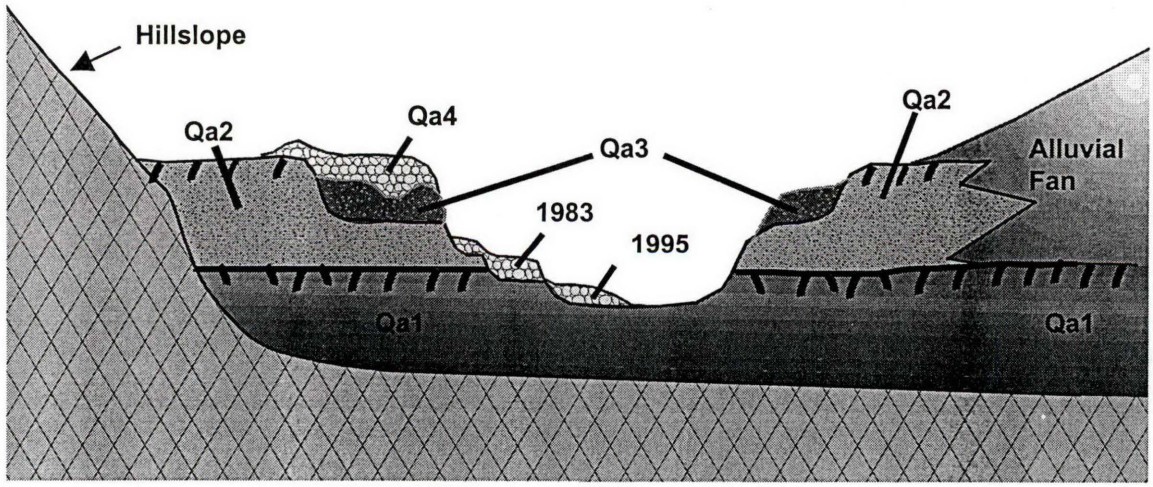


Figure 5. Schematic diagram of regional, Mid- to Late Holocene stratigraphy

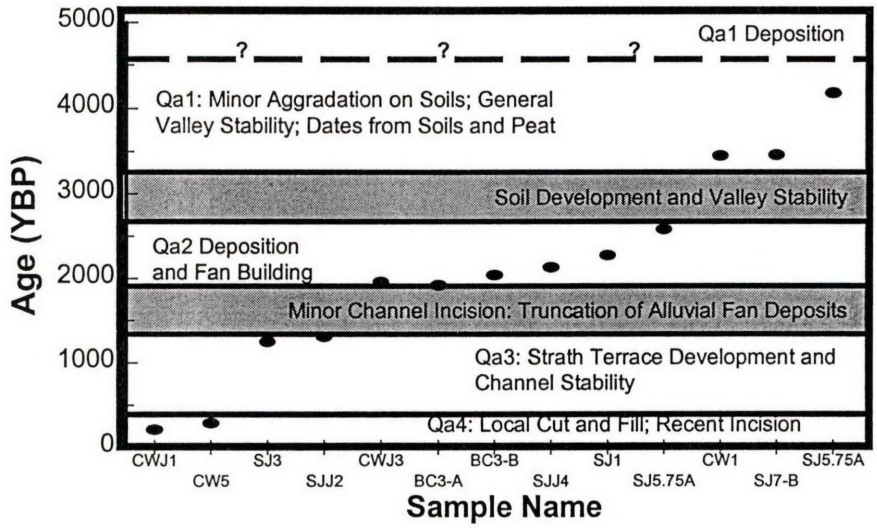


Figure 6. Radiocarbon dates obtained from valley fill materials in San Juan and Barley Creeks.

Table 1. Summary of radiocarbon dates obtained on valley fill deposits within central Nevada.

Qa6		Tree Rings	1983	
Qa5		Tree Rings	1971	
Unit	**Sample #**	**Material Dated**	**Time (yr BP)**	**Error (yrs)**
Qa4	CWJ1	Charcoal	210	50
	CW5	Charcoal	290	50
Qa3	SJ3	Bulk Organics	1250	50
	SJJ2	Charcoal	1310	50
Qa2	CWJ3	Charcoal	1960	50
	BC3-A	Charcoal	1920	60
	BC3-B	Charcoal	2040	60
	SJJ4	Charcoal	2130	50
	SJ1	Peat	2270	60
	SJ5.75A	Charcoal	2580	70
Qa1	CW1	Charcoal	3450	160
	SJ7-B	Charcoal	3460	70
	SJ5	Charcoal	4180	100

Figure 7. Qa1, characterized by well developed soil buried beneath Qa2.

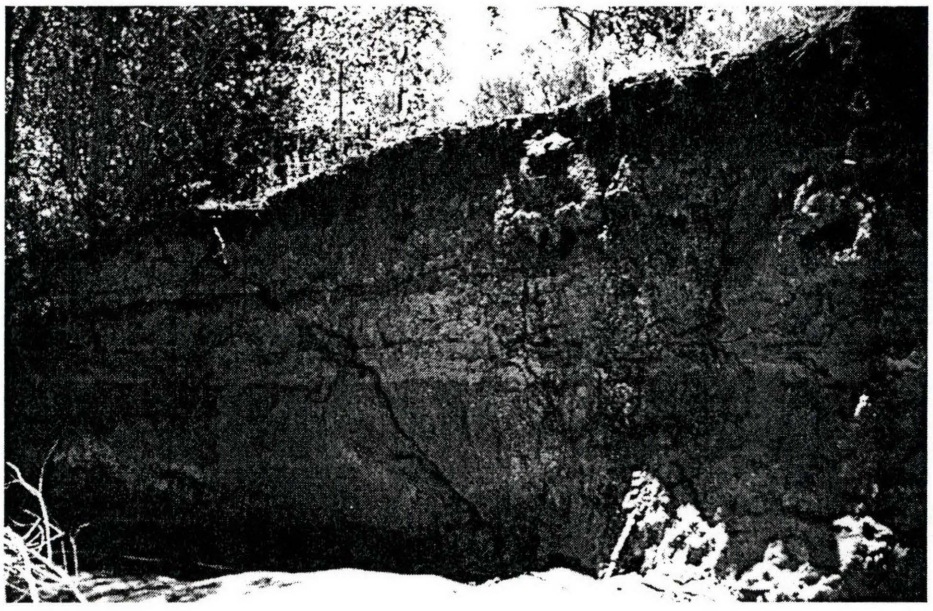


Figure 8. Qa2 within San Juan Creek. Note well-developed soil at surface.

Figure 10. Qa4 paleochannel fill deposits along Cottonwood Creek.

Figure 11. Qa4 overbank gravel deposits along Cottonwood Creek.

Figure 12. Qa7 deposits, inset below valley floor, along San Juan Creek.

units have been estimated by dendrochronologically dating willows growing on the surface of the deposits. They correspond to years of unusually large spring floods including 1995 (Qa7), 1983 (Qa6), and the early 1970s (Qa5).

C. Climatic Influences on Geomorphic Processes

The similarities in the nature and timing of erosional and depositional events within upland watersheds of central Nevada suggest that these geomorphic events were initiated by disturbances which could affect large areas of the Great Basin. Given that the watersheds are characterized by differing tectonic regimes, and the changes in channel form and process predate European settlement, the most likely cause is climatic change. It follows, then, that the timing of major geomorphic events should correlate with the timing of climatic alterations documented using climate proxy data from central Nevada. As part of the Forest Service's Ecological Management Project (FSEMP), Robin Tausch has used data from woodrat middens to reconstruct paleoenvironments during the Holocene within our study area. To date, a total of 18 different strata have been sampled from three woodrat middens located within the Birch and Big Creek basins positioned adjacent to the watersheds examined in this investigation (Chambers et al. 1998). The midden strata range in age from 100 to 8,900 YBP and, together with the modern community, include a total of 236 taxa (Chambers et al. 1998). Interpretation of the woodrat data suggests that the climatic patterns in central Nevada are similar to those deciphered from other climate proxy data from the Great Basin, although minor variations in the timing of the climatic shifts are apparent (Fig. 13). Perhaps of most significance is the discrepancy in the timing of the Neoglacial. Earlier studies suggest that regionally, the cool, moist conditions associated with the Neoglacial continued until approximately 2,000 YBP, whereas the local data show that a decline in the diversity of hillslope plant species had clearly begun by 2,500 YBP. Both show, however, that the Neoglacial was followed by a significant drought, and given the temporal and spatial variability associated with climate change processes, it is not surprising that minor variations in the timing of climatic shifts are apparent on a local scale.

In general, erosional and depositional events observed within the upland basins closely parallel major shifts in climatic regime. Radiocarbon dates obtained from the oldest unit (Qa1) range in age from 4,180-3,450 YBP and correspond to the Neoglacial, a period characterized by a high number of plant taxa. As noted above, these dates were obtained from charcoal found within soil A-horizons or buried peats that immediately overlie mineral horizons. Thus, the deposition of Qa1 must have primarily occurred prior to approximately 4,200 YBP, and valley floors, characterized by an episode of soil develop and local peat accumulation, were apparently stable during the latter part of the Neoglacial. Qa2, underlies most of the valley floor in these watersheds and buries Qa1. It interfingers with alluvial fan deposits indicating they were syndepositional. Radiocarbon analysis of charcoal constrain the age of Qa2 from 1,960 to 2,580 YBP, or the onset of a severe drought following the Neoglacial, when the diversity of local vegetation dropped by 50 % or more (Fig. 13). Thus, it appears that the initiation of

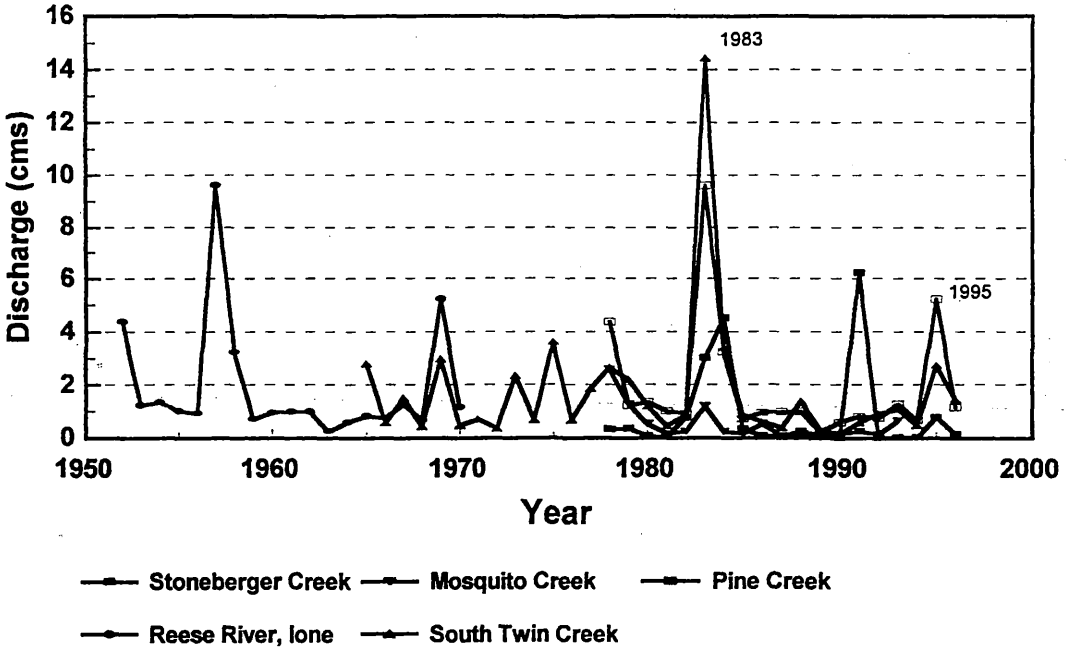


Figure 13. Discharge measurements at USGS gaging stations within central Nevada

hillslope erosion, fan building, and valley deposition is associated with a climatic shift from moister to drier conditions.

Earlier studies in arid climatic regimes have recognized periods of increased hillslope erosion resulting from a change to drier, warmer conditions (Bull and Schick,1979; Wells et al., 1987). Explanations of the seemingly discordant relationship between increased sediment yield and decreasing effective precipitation is based on the assumption that both runoff and sediment availability are enhanced by a decline in hillslope vegetation. Wells et al. (1987) suggest that increased runoff can also result from changes in the infiltration capacity of the hillslope soils. In the case of the Mojave Desert where they were working, they argued that the deposition of fine-grained, eolian sediment increased rates of hillslope pedogenesis and decreased infiltration capacities of the soils. The net affect was increased runoff from the less permeable hillslopes, that when combined with increased sediment availability associated with the decline in vegetation density, resulted in fan aggradation in spite of increasing aridity.

We envision a model similar to that first proposed by Bull and Schick (1979) and later modified by Wells et al. (1987) in which a decline in vegetation density caused by a shift to drier, warmer conditions increased runoff and hillslope erosion. The change in sediment and water production initiated an episode of side-valley alluvial fan building and aggradation within the valley bottoms. An abundance of charcoal occurring in thin, but distinct layers within Qa2 deposits suggest that numerous wildfires may have occurred during the drought associated with Qa2. It seems likely these fires would have increased hillslope sediment availability and runoff, exacerbating aggradation at the base of the slopes.

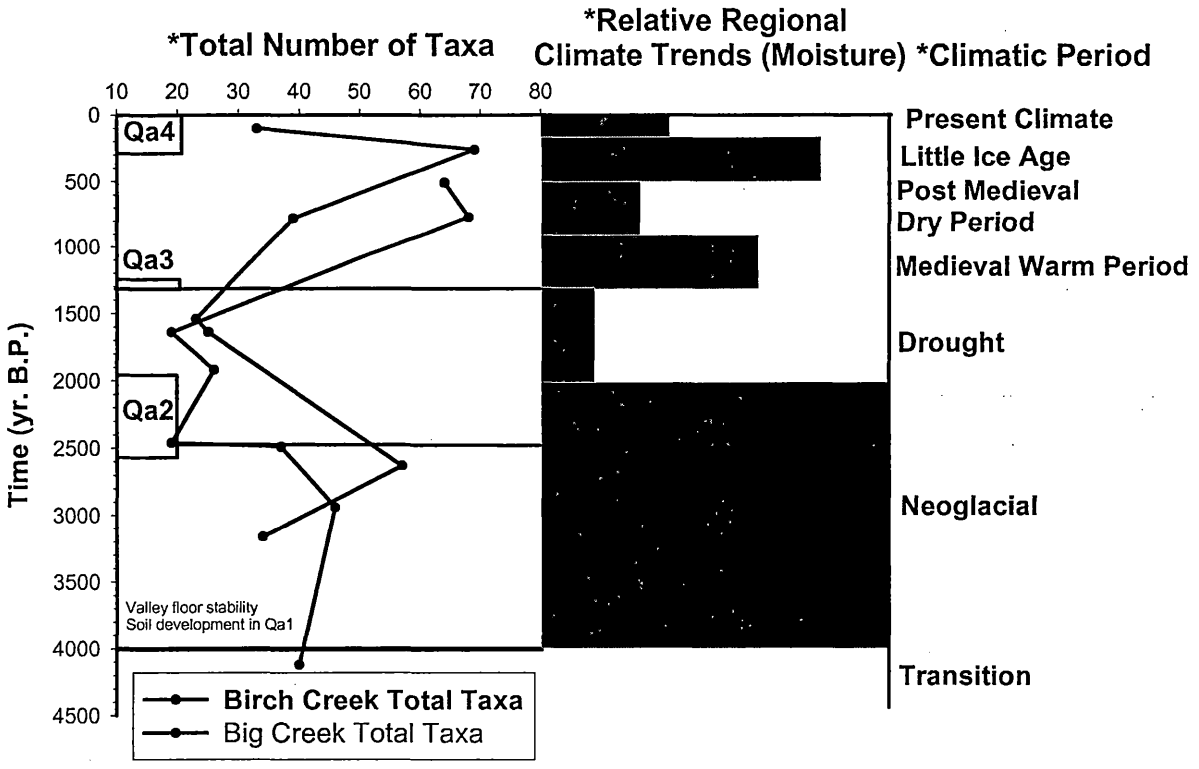
Interestingly, data from local woodrat middens and other climate proxy indicators from the Great Basin suggest that the drought conditions lasted until about 1,300 YBP (Fig. 13). However, radiocarbon dates of charcoal collected from the top of Qa2 deposits indicate that aggradation declined dramatically after approximately 1,900 YBP and was followed by a period of minor entrenchment. Bull (1991) has argued that aggradational and erosional processes can be significantly affected by changes in the availability of sediment on the hillslopes (i.e., within sediment reservoirs) during an erosional event. It seems plausible that the decline in fan and valley aggradation during the latter part of the drought was initiated by a reduction in the availability of fine-grained materials on the hillslopes. This is supported by the fact that Qa2 within the upland basins are dominated by fine-grained sediments, and modern hillslope materials are characterized by relatively coarse debris. Moreover, where fine sediments are abundant on the hillslopes, they are overlain by a surface mantle of coarse debris.

It is not clear at this time whether incision following Qa2 deposition occur during drought conditions, or during the onset of the Medevil Warm Period. Wells et al. (1987) argue that once the hillslope erosion has depleted the sediment reservoirs, fan entrenchment can occur even though climatic conditions may not have changed. Application of this argument to the upland basins of central Nevada would suggest that minor valley entrenchment following the deposition of Qa2 may have occurred while

drought conditions persisted in the area. However, the winnowing of fine-grained sediments from the hillslopes would presumably have increased the infiltration capacities of the soils and reduced overland flow. In this case, it seems unlikely that incision of the axial channel system would have occurred during the latter part of the drought. Thus, we suggest that the entrenchment occurred with the onset of moister conditions associated with the Medevil Warm Period. In either case, radiocarbon dates from the base of Qa3 deposits (ranging from 1,310-1,250 YBP) suggest that the Medevil Warm Period is primarily associated with lateral planation and the development of a strath terrace that is inset into the both Qa2 deposits and the side-valley alluvial fans. There is no evidence to suggest that fan building has occurred anytime since the deposition of Qa2 deposits. The increase in hillslope vegetation is likely to have stabilized the slopes and allowed for an overall period of valley floor stability characterized by lateral planation of the axial channels. Valley and channel stability apparently continued until approximately 290 YBP when localized incision, and the subsequent deposition of Qa4, began.

Qa4 deposits are characterized by a variety of depositional styles including paleochannel fills and overbank gravel deposits. They are also geographically limited to channel reaches located immediately upstream of side-valley alluvial fans which extend across the valley floor. A more detailed discussion of the possible controls on their distribution is presented below. It is important to recognize here, however, that localized incision within the upland watersheds began during the Little Ice Age (500 to 150 YBP) which was a cool, wet period with an abundance of vegetation. Thus, Qa4 deposition began at least a century before the onset of European settlement. Unlike units Qa2 and Qa3, the timing of Qa4 deposition does not closely parallel significant changes in the late Holocene climatic conditions (Fig. 13). Nevertheless, there is some evidence in central Nevada suggesting that around 250 YBP, the approximate timing of Qa4 deposition, climate began to shift to warmer and drier conditions, that are similar to that of today (Tausch and Nowak, 1997).

While incision that created the paleochannels associated with Qa4 deposition is highly localized, a major episode of channel entrenchment has more recently occurred. Associated with this phase of channel cutting is the deposition of units Qa5-Qa7, which occurs as small, gravel terraces inset below the valley floor. The maximum ages of the willows growing on each of these surfaces have been determined at 8 sites in 5 different watersheds of the Toiyabe Range by ring-counts (Chambers et al., 1998). Results show that willow stands of similar maximum ages occur on each of the surfaces of similar height above the channel. The maximum willow age within a stand appears to be highly correlated with the timing of major floods, including episodes in 1983, 1978, 1975, and 1973 (Fig. 14). The close relationships between willow age and terrace height suggest that the surfaces were colonized following incision by significant flood flows. These observations are consistent with data collected at permanently monitored cross-sections which illustrate that during the past 4 years, most of the entrenchment was associated with the 1995 flood event (Chambers et al., 1998). Modern entrenchment of the channel systems is clearly dominated by sediment deficient, high magnitude floods.



*Adapted from: Tausch, Robin and Nowak, Cheryl. 1997. Holocene Paleoecology of Central Nevada. USDA Forest Service, Rocky Mountain Research Station Reno, Nevada

Figure 14. Relations between alluvial stratigraphic units in central Nevada and the timing of climatic shifts.

D. Influence of Side-Valley Alluvial Fan Evolution on Axial Channel Stability

Incision is a significant, basin wide process that is currently underway in nearly all of the watersheds that were examined in central Nevada. However, the rate and magnitude of incision are not uniformly distributed along the channel, but varies as a function of distance from alluvial fans that are associated with, and create the stepped longitudinal valley profiles. The most significant cutting is located along the channel where it traverses the toe of the side-valley fans and immediately upstream of these fan units within wet meadow complexes. Knickpoints developed in fan deposits, or less frequently, bedrock are common along these reaches.

Presumably, it is the dramatic drop in elevation of both the valley floor and the channel bed that occurs as the axial stream traverses the fan toes that is causing the incision to be concentrated in these areas. In other words, the streams are trending toward a "smooth" concave-up profile typically assumed to represent the equilibrium form. This implies that the alluvial fans are acting as local base level controls that dictate the local rates of entrenchment.

Narrow valley widths which confine flood waters, combined with relatively steep channel gradients, increase the erosive potential of flood flows along stream reaches located at the fan toes. However, the increase in erosive force of the flows is offset by (1) an increase in the size of the channel bed material, and (2) the localized exposure of bedrock within the channel floor. Bedrock exposures result from the fact that the axial channel systems traverse the alluvial fans along the fan-hillslope contact where valley floor elevations are the lowest, the precise location where bedrock is least likely to have been significantly eroded during earlier phases of valley entrenchment.

While incision is the dominate process along the axial streams, the relatively recent deposition of Qa4 sediments in paleochannels and as overbank deposits has occurred immediately upstream of the alluvial fans. It appears that Qa4 aggradation is a temporary phenomenon that is primarily related to the instantaneous influx of sediment to an otherwise sediment starved channel. For example, a recent episode of channel filling and overbank deposition occurred along Cottonwood Creek at site CW-4, located immediately upstream of an alluvial fan that extends across the valley floor. The ultimate product of this event was channel avulusion and the development of a new channel cut into older Qa4 deposits which underlie a wet meadow complex. Field observations reveal that the sediment which was locally deposited upstream of the fan had previously been stored behind a series of beaver dams. These sediments were later eroded when the dams were breached by spring flood waters in 1983. They were subsequently redeposited downvalley, upstream of the side-valley fan. The deposition of gravels upstream of the fans is presumably related to (1) reduced channel gradients as the streams approach the fans (Fig. 3), and (2) a bottle-neck affect, where flood waters are temporarily ponded upstream of the fan deposits.

It is interesting to recognize that the reaches located upstream of the fans are currently characterized by long-periods of incision, separated by temporary episodes of channel filling, overbank deposition, and avulusion. Radiocarbon dates obtained on Qa4 deposits preserved within bank exposures suggest that the alteration of aggradation and erosion have been ongoing processes for at least the past 290 years. Given that the alluvial fans are acting as local base level controls, and that localized incision and deposition is significantly influenced by the stepped longitudinal configuration of the valley floors, then some stream reaches are inherently unstable. Moreover, the instability is the direct result of the depositional patterns within the valley bottoms that occurred approximately 2000 years ago.

E. Geomorphic Responses to Anthropogenic Disturbances

The cause of the most recent phase of incision has become the center of intense debate. It is generally assumed that recent entrenchment is primarily related to anthropogenic disturbances associated with European Settlement the during mid- to late 1800s and early 1900s. However, a number of investigators have recently argued that incision during the past two centuries throughout much of the western U.S. is related in large part to minor changes in climatic regime (McFadden and McAuliffe, 1997; Balling and Wells, 1990). The data presented above strongly suggest that upland watersheds of central Nevada were inherently prone to incision prior to Anglo-American settlement due to (1) the stepped nature of the longitudinal valley profiles associated with side-valley fan deposition, and (2) the lack of available sediment on the hillslopes following the phase of fan building and valley aggradation between approximately 1900 and 2500 YBP. Nonetheless, is seems likely that anthropogenic disturbances that enhance runoff are likely to exacerbate channel incision. Within the watersheds examined here the most significant widespread disturbance is likely to be livestock grazing which has been occurring in the area sense at least the 1850s. Trimble and Mendel (1995) argue that cattle directly reshape the earth by compacting the soil, thereby reducing its bulk density and infiltration capacity. Lowered infiltration capacities, combined with reductions in surface roughness, will undoubtedly increase hillslope runoff and promote channel incision, especially given the sediment starved condition of the slopes within the watersheds (Trimble and Mendel, 1995; Armour et al., 1994).

While livestock grazing may have promoted channel entrenchment, one of the most significant anthropogenic impacts is associated with intense gullying of access roads. Locally, these gullies reach depths below the bed of the adjacent channel, and thus, are able to capture axial channel flow during high magnitude events. In fact, major shifts in channel position were recognized in several locations within San Juan Creek as well as within other basins of central Nevada during the high runoff season of 1998 (Fig. 15). Road gullying and channel capture has undoubtedly exacerbated, and in some cases, initiated channel incision within the watersheds.

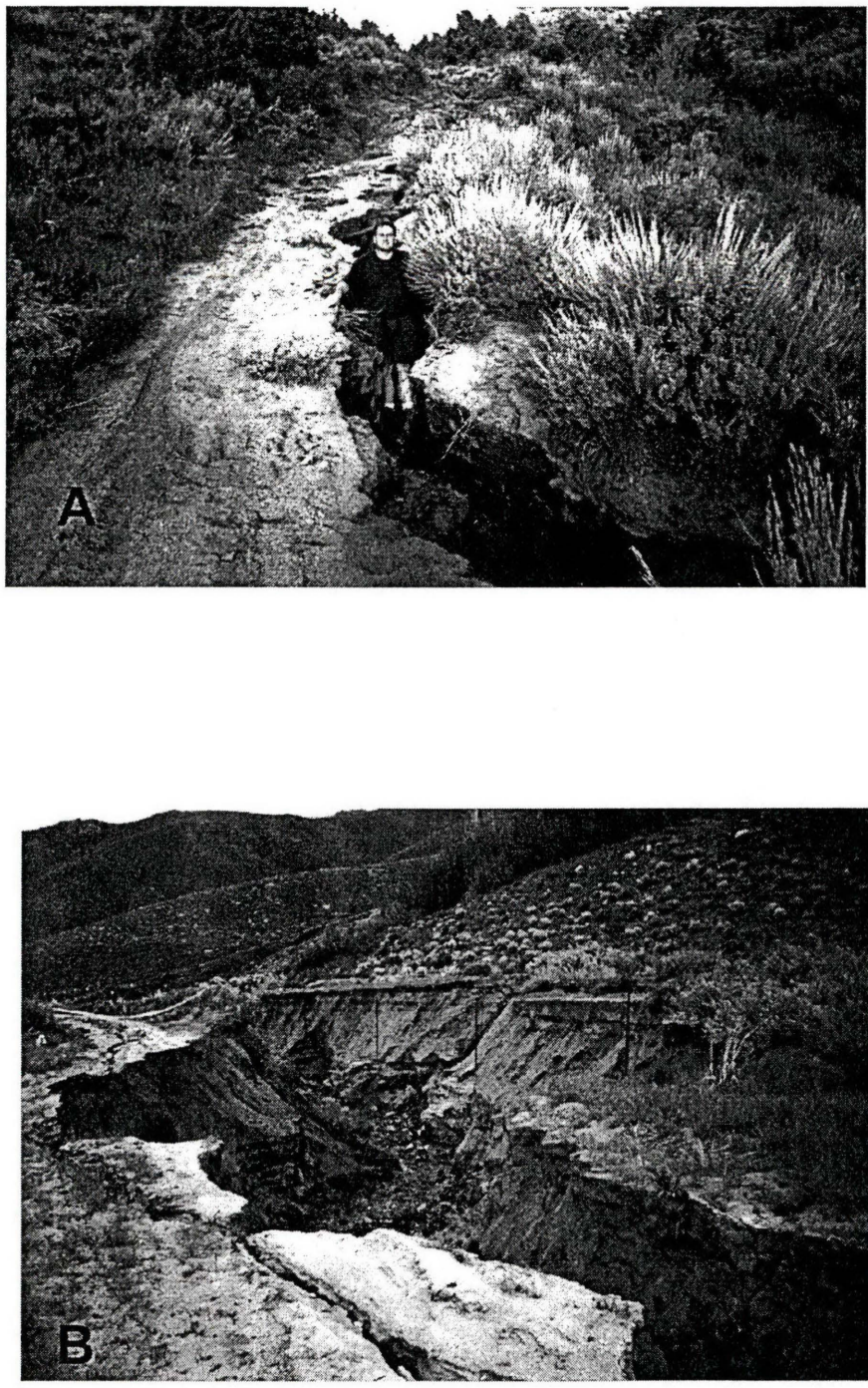


Figure 15. (A) Gully developed in access road within Slaugherhouse Canyon, central Nevada; (B) Gully developed in access road within Marshall Canyon during the spring, 1998..

V. ACKNOWLEDGMENTS

Much of the work contained within this report was performed in conjunction with Dr. Dru Germanoski from Lafayette College. A number of students also participated in data collection and interpretation including Robert Barr, Michael Potter, Dorthea Richardson, and Karen Waltman.

VI. REFERENCES

Armour, C., D. Duff, and W. Elmore. 1994. The effects of grazing on western riparian and stream ecosystems. Fisheries 19:9-12.

Balling, R. C., Jr. and S. G. Wells. 1990. Historic rainfall patterns and arroyo activity within the Zuni River drainage basin, New Mexico. Annals of the Association of American Geographers 80:603-617.

Birkeland, P.W., 1984. Soils and Geomorphology: Oxford University Press, New York, 372 p.

Bull, W.B. 1991. Geomorphic Response to Climatic Change. Oxford University Press, New York, 575p.

Bull, W.B. and A.P. Schick. 1979. Impact of climatic change on an arid watershed, Nahal Yael, southern Israel. Quaternary Research 11: 153-171.

Chambers, J. C., K. Farleigh, R. J. Tausch, J. R. Miller, D. Germanoski, D. Martin, and C. Nowak. 1998. Understanding long-and short-term changes in vegetation and geomorphic processes: the key to riparian restoration. Proceedings: Rangeland Management and Water Resources. American Water Resources Association and Society for Range Management, Reno, NV, May 28-29, 1998 (in press).

Chatters, J. C. and K. A. Hoover. 1992. Response of the Columbia River fluvial system to Holocene climatic change. Quaternary Research 37: 42-59.

Frissell, C.A. and Nawa, R.K., 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management, 12: 182-197.

Hereford, R. 1987. The short term: Fluvial processes. Pages 276-288 in W.L. Graf, ed., Geomorphic Systems of North America, The Decade of North American Geology. Geological Society of America Centennial Special Volume.

Hereford, R. 1984. Climate and ephemeral-stream processes: twentieth-century geomorphology and alluvial stratigraphy of the Little Colorado River, Arizona. Geological Society of America Bulletin 95:654-668.

Hess, G. W. and L. R. Bohman. 1996. Techniques for estimating streamflow at gaged sites and monthly streamflow duration characteristics at ungaged sites in central Nevada. US Geological Survey, Carsen City, Nev. Open-File Rep. 96-559.

Karlstrom, E.T., T.N.V. Karlstrom, 1986. Late Quaternary alluvial stratigraphy and soils of the Black Mesa-Little Colorado River areas, northeastern Arizona. Pages 71-92 in J.D. Nations, C.M. Conway, and G.A. Swann, eds., Field Trip Guidebook for Geological Society of America Rocky Mountain Section Meeting, Flagstaff, AZ.

Karlstrom, T.N.V., G.J. Gumerman, and R.C. Euler. 1974. Paleo-environmental and cultural changes in the Black Mesa region northeastern Arizona. Pages 768-792 in T.N.V. Karlstrom, G.A. Swann, and R.A. Eastwood, eds., The Geology of Northern Arizona with Notes on Archaeology and Paleoclimate. Geological Society of American Rocky Mountan Section Meeting, Flagstaff, AA.

Kleinhample, F. J. and J. I. Ziony. 1985. Geology of Northern Nye County, Nevada. Nevada Bureau of Mines and Geology, Bulletin 99A. University of Nevada, Reno. 172 pp.

McFadden, L. D. and J. R. McAuliffe. 1997. Lithologically influenced geomorphic responses to Holocene climate changes in the southern Colorado Plateau, Arizona: a soil-geomorphic and ecological perspective. Geomorphology 19:303-332.

O'Neil, J. and Fitch, L., 1992. Performance audit of instream habitat structures constructed during the period 1982-1990, in south-western Alberta. Page 4 in Abstract for meeting of the American Fisheries Society, September, 1992, Rapid City South Dakota.

Ritter, J.B., J.R. Miller, Y. Enzel, and S.G. Wells. 1995. Reconciling the roles of tectonism and climate in Quaternary alluvial fan evolution. Geology 23: 245-248.

Soil Conservation Service, 1981. Examination and description of soils in the field, in Soil Survey Manual: U.S. Department of Agriculture-SCS, U.S. Government Printing Office, Washington, D.C.

Trimble, S. W. and A. C. Mendel. 1995. The cow as a geomorphic agent - a critical review. Geomorphology 13:233-253.

USDA Forest Service. 1996. Central Nevada riparian field guide. USDA Forest Service, Intermountain Region. R6-ECOL-TP.

Waltman, K., Miller, J., Germanoski, D., Chambers, J. and Tausch, R., 1998. Relations between Climate and Geomorphic Responses in the Cottonwood Creek Watershed, Toiyabe Mountains, Central Nevada. 1998 GSA Program with Abstracts, Annual Meeting, Toronto.

Wells, S.G., L.D. McFadden, and J.C. Dohrenwend. 1987. Influence of late Quaternary climatic changes on geomorphic and pedogenic processes on a desert piedmont, eastern Mojave Desert, California. Quaternary Research 27: 130-146.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions of American Geophysical Union 35:951-956.

APPENDIX A

Measured Stratigraphic Sections within the San Juan and Cottonwood Creek Basins

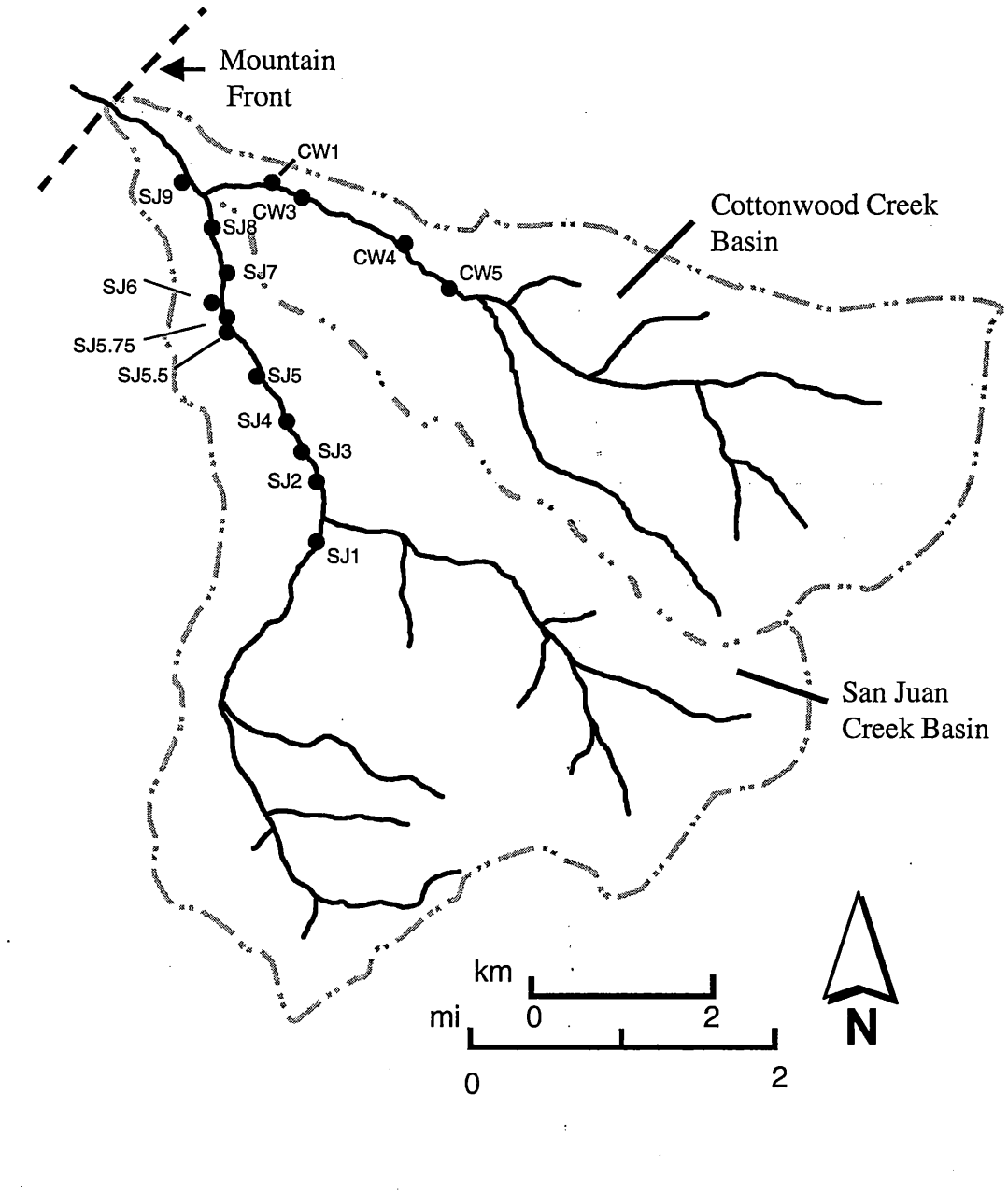
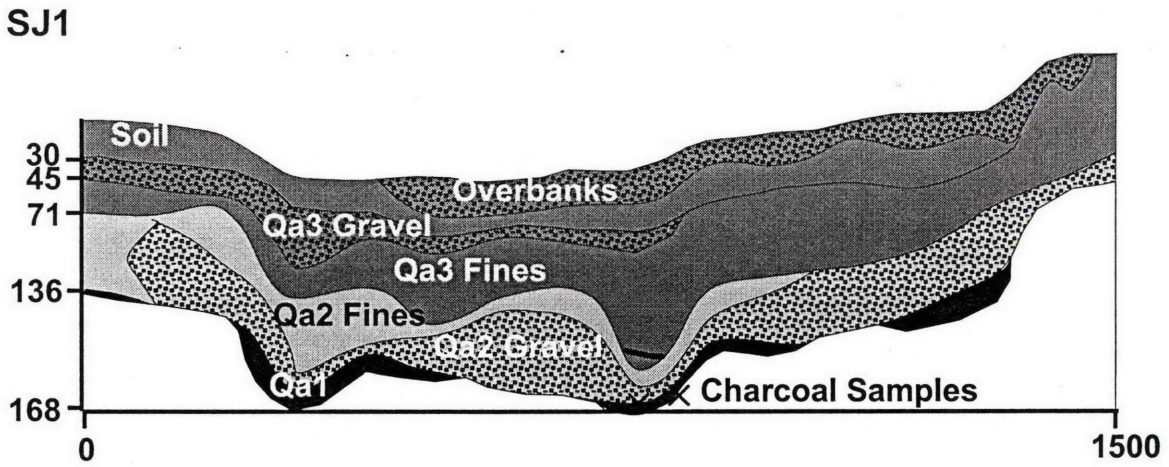
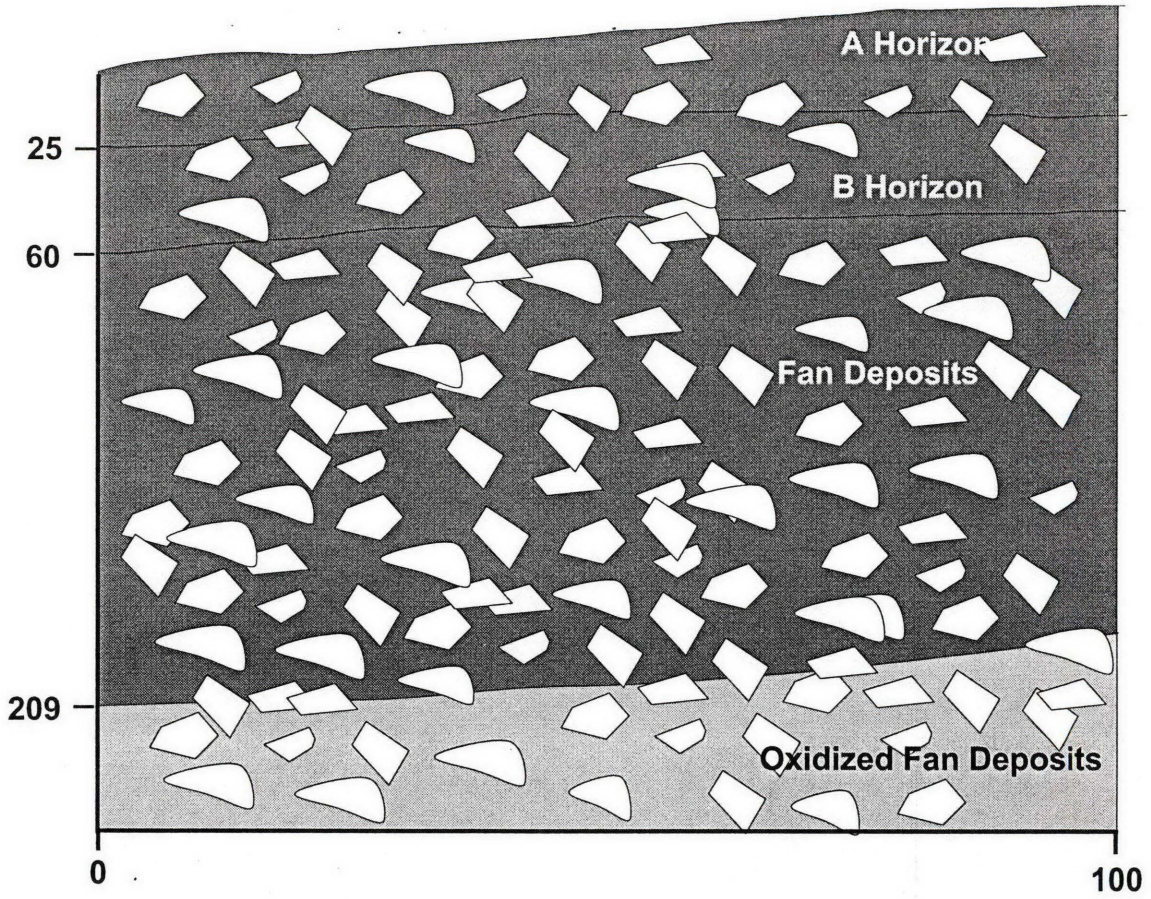


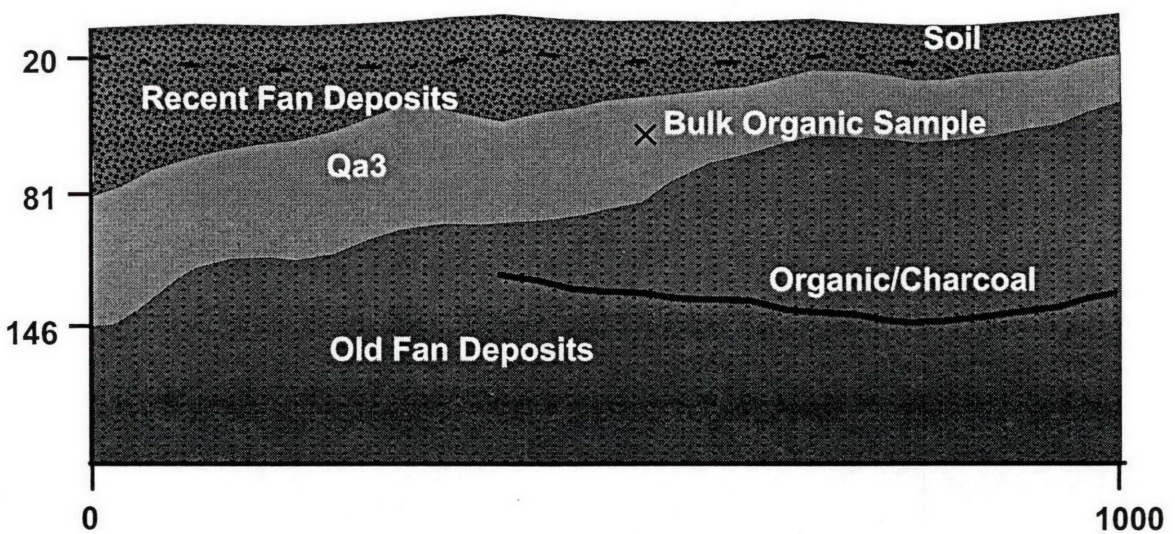
Figure A-1. Location of measured stratigraphic sections within the San Juan and Cottonwood Creek basins.


SJ1
Soil
Overbanks
Qa3 Gravel
Qa3 Fines
Qa2 Fines
Qa2 Gravel
Qa1
Charcoal Samples
30
45
71
136
168
0
1500

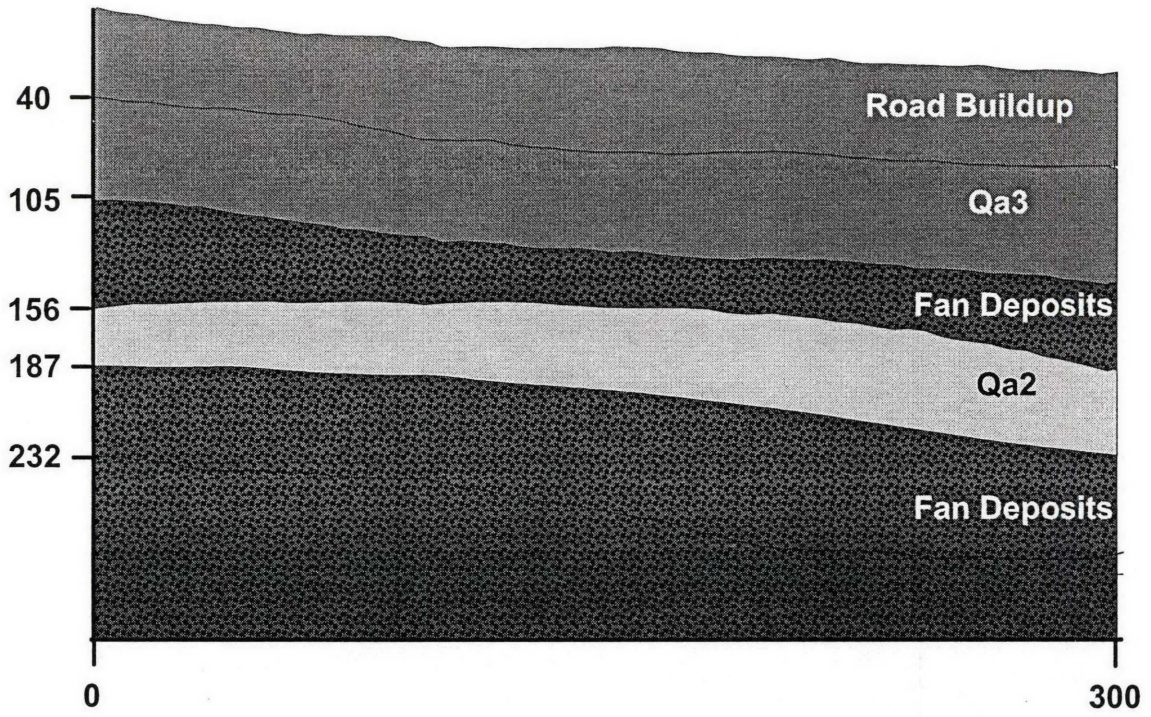
SJ2


A Horizon
B Horizon
Fan Deposits
Oxidized Fan Deposits
25
60
209
0
100

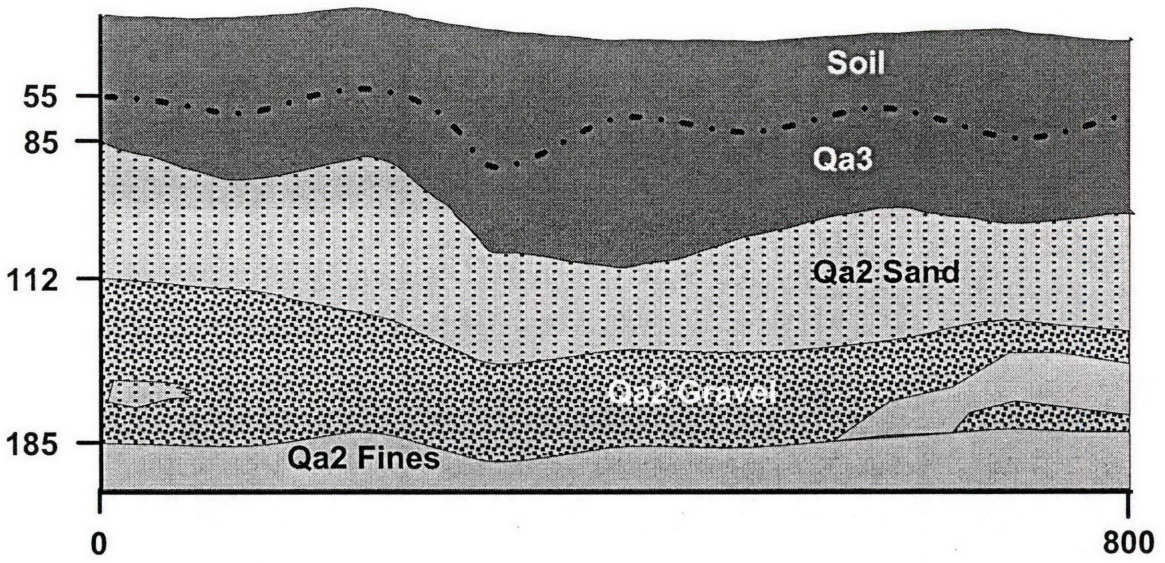
SJ3


Soil
20
Recent Fan Deposits
Bulk Organic Sample
Qa3
81
Organic/Charcoal
146
Old Fan Deposits
0
1000

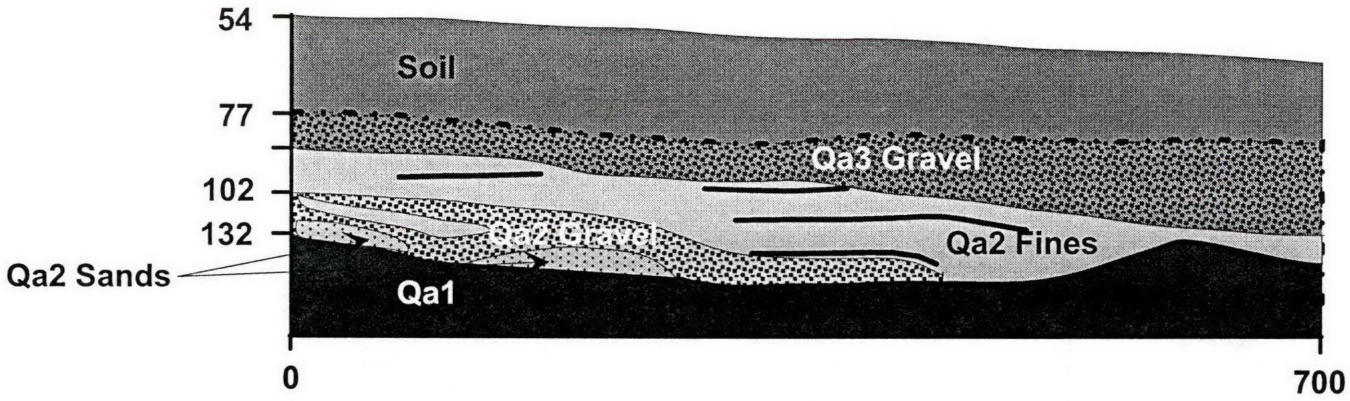
SJ4

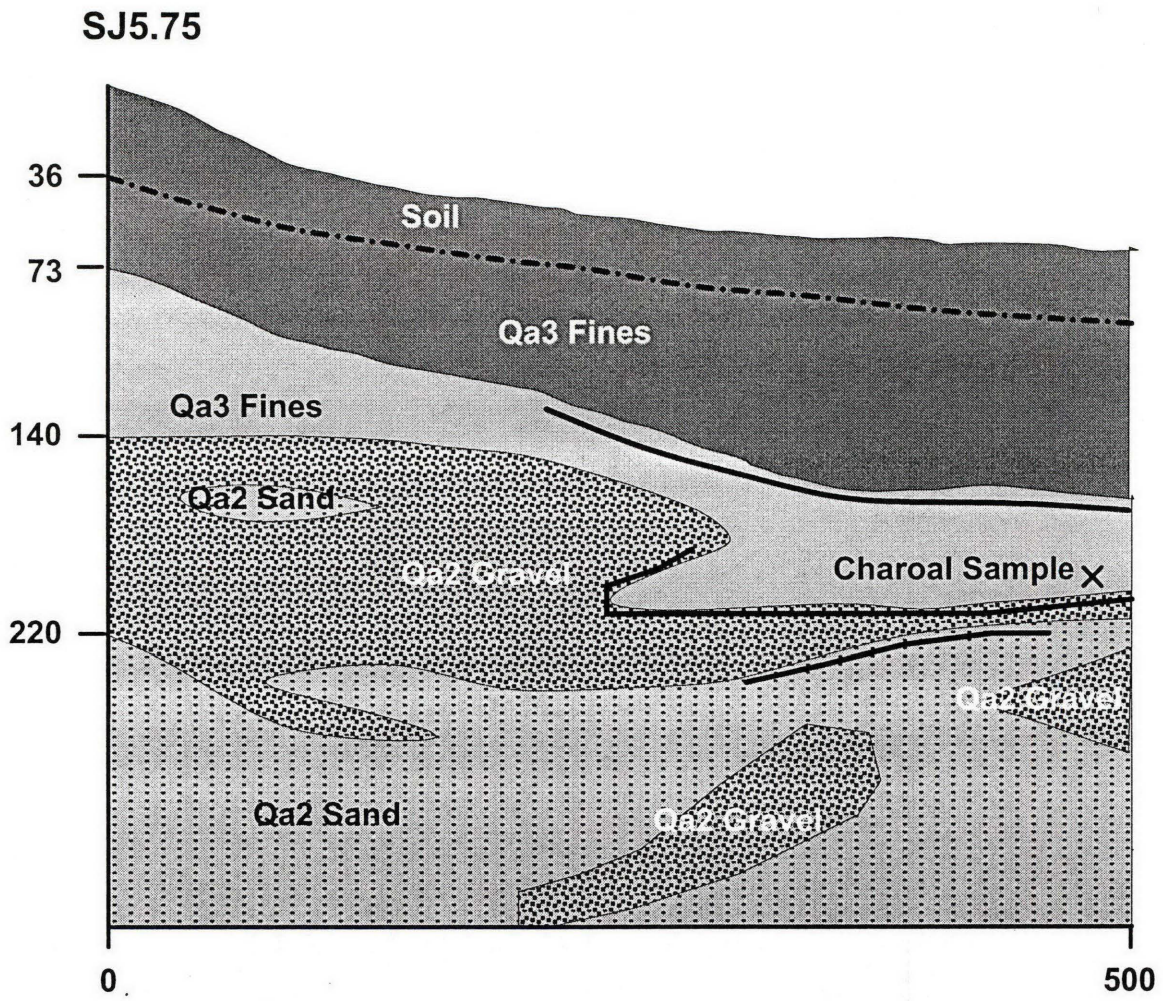

40
105
156
187
232
Road Buildup
Qa3
Fan Deposits
Qa2
Fan Deposits
0
300

SJ5

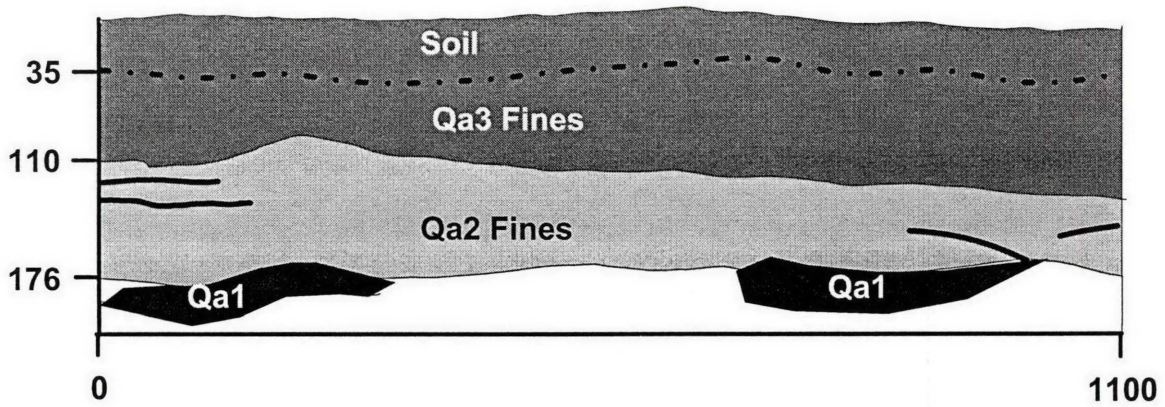


SJ5.5

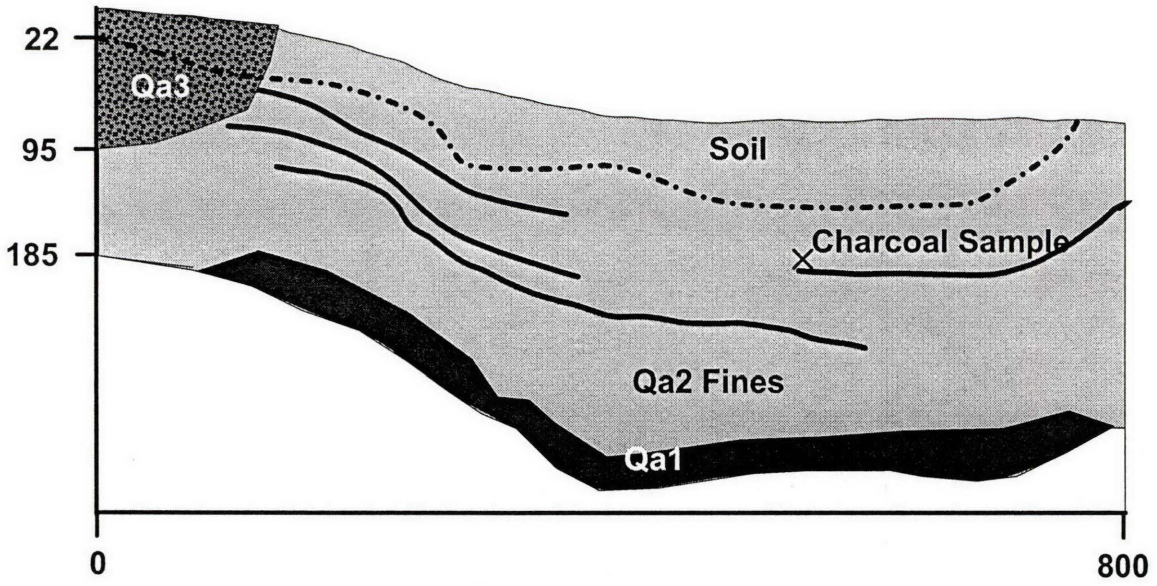

54
77
102
132
Soil
Qa3 Gravel
Qa2 Gravel
Qa2 Fines
Qa2 Sands
Qa1
0
700


SJ5.75
36
73
140
220
0
500
Soil
Qa3 Fines
Qa3 Fines
Qa2 Sand
Qa2 Gravel
Charoal Sample
Qa2 Gravel
Qa2 Sand
Qa2 Gravel

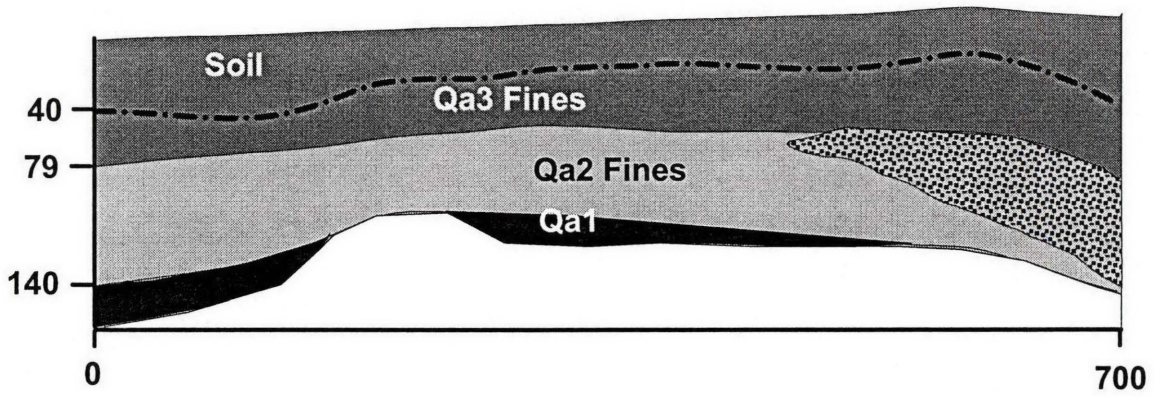
SJ6

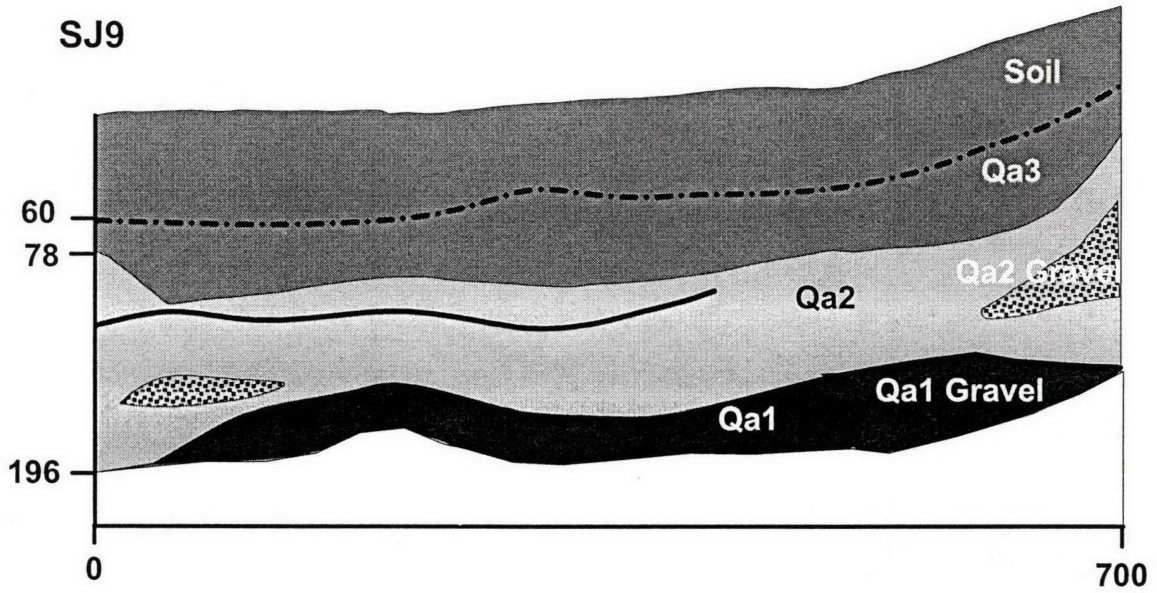


SJ7

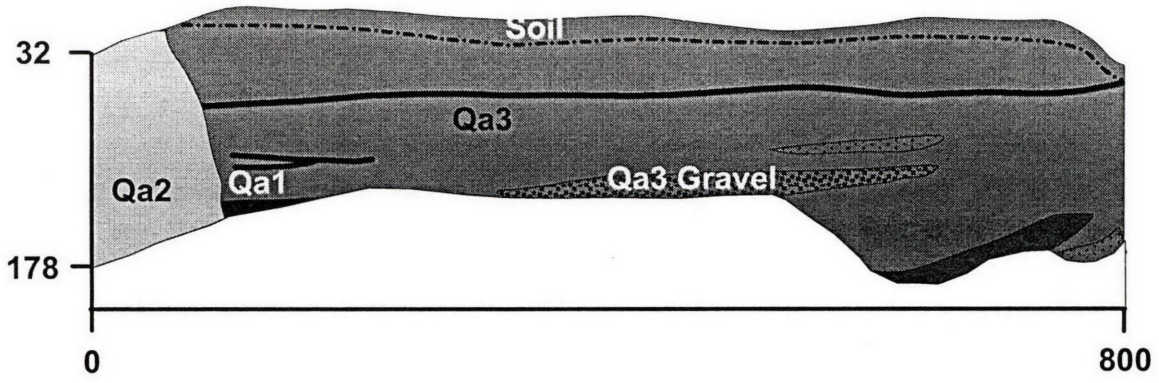


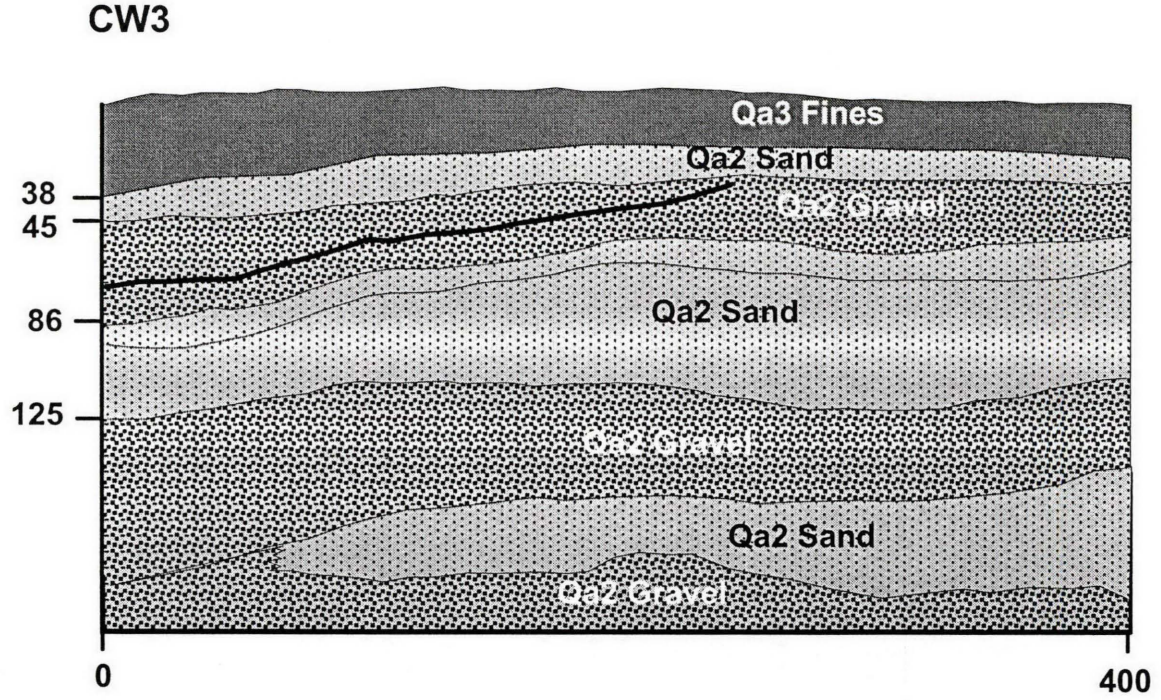
SJ8



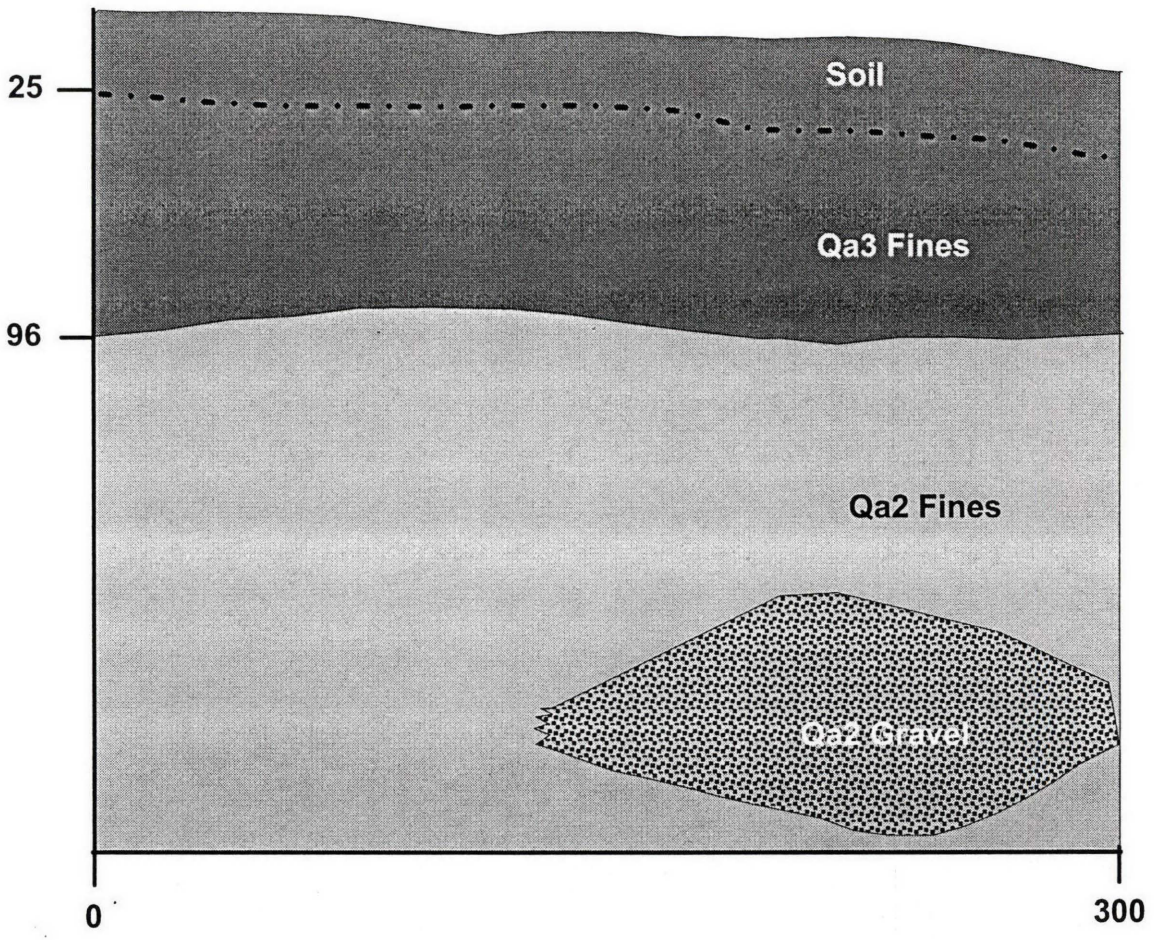

SJ9
Soil
Qa3
60
78
Qa2
Qa2 Gravel
Qa1 Gravel
Qa1
196
0
700

CW1

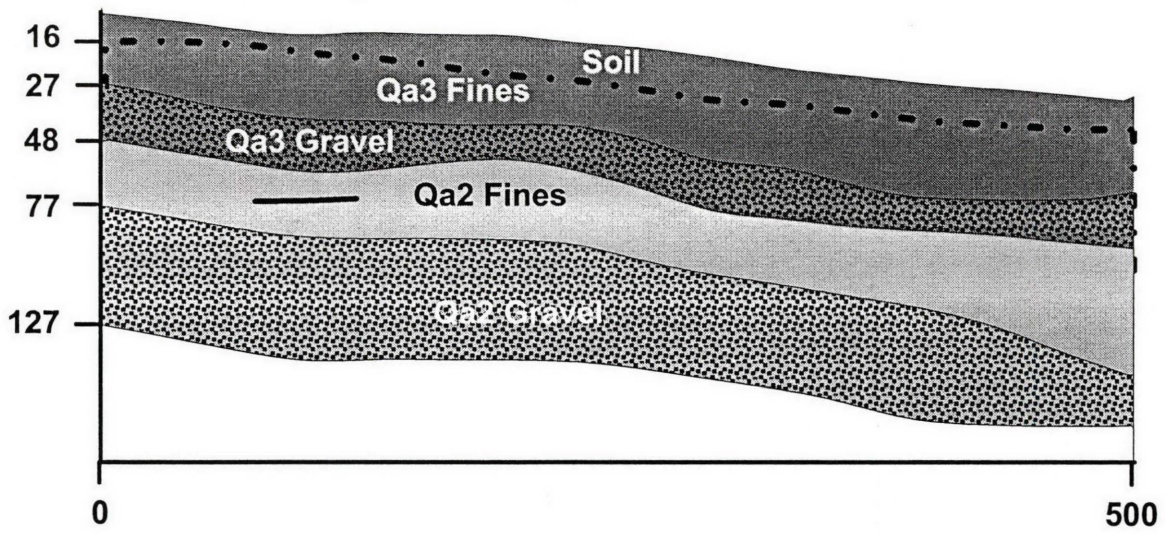



CW3
Qa3 Fines
Qa2 Sand
Qa2 Gravel
Qa2 Sand
Qa2 Gravel
Qa2 Sand
Qa2 Gravel
38
45
86
125
0
400

CW4



CW5


16
27
48
77
127
Soil
Qa3 Fines
Qa3 Gravel
Qa2 Fines
Qa2 Gravel
0
500